Nature Conservation

Nature Conservation 63: 37–57 (2026)
DOI: 10.3897/natureconservation.63.177517

Research Article

Conservation of threatened vascular plants in intensive agricultural landscapes in Canada

Vladimir Kricsfalusy[1]

1 *School of Environment and Sustainability, University of Saskatchewan, 117 Science Place, Saskatoon, Saskatchewan, S7N 5C8, Canada*
Corresponding author: Vladimir Kricsfalusy (vladimir.k@usask.ca)

Abstract

With a steadily shrinking natural landscape in the province of Saskatchewan, Canada, mainly caused by intensive agriculture, conservation of threatened plants *in situ* should become a priority to prevent their extinction. The aim of this study is to identify native vascular plants at risk in the Redberry Lake Biosphere Region (RLBR) to support evidence-based conservation management. Such criteria as species distribution, richness, population size, habitat affinities, existing threats, conservation status, and gaps in the current protection were applied to develop the conservation strategies. The field surveys were conducted during 2010–2025 in various habitats of the RLBR within the Prairie and Boreal Plain ecozones. In total, 46 taxa (31 species, 5 subspecies and 10 varieties) of conservation concern in 19 families and 34 genera were identified. The top represented families Orchidaceae, Cyperaceae, and Poaceae and such genera as *Carex*, *Cypripedium*, and *Potentilla* make the largest contribution to the threatened flora. The study revealed that the majority of species occurrences and richness hotspots with 5–10 species each are concentrated in the Aspen Parkland ecoregion of the Prairie ecozone. It was found that most threatened plants occur in a few isolated sites, and their survival depends on the small population size as the consequence of recent habitat loss due to human activities. The conducted analysis identified seven hotspots of species richness, including three of them outside of the core area and the buffer zone of the RLBR designated for biodiversity protection.

Threatened plants were categorized under the NatureServe criteria at the subnational (provincial) level as follows: S1– Critically Imperiled/Extremely rare (2 taxa), S2– Imperiled/Very rare (7), and S3– Vulnerable/Rare to uncommon (37). Among them, five species were assessed at the national level (N3) and two species at the global level (G3). Two S3 species from this listing are simultaneously ranked as VU– Vulnerable and NT– Near Threatened under the IUCN criteria. It was found that threatened plants are vulnerable to habitat loss, successional overgrowth, spread of invasive alien species, and wetland interventions. These threats are resulting from land use history, current unsustainable agricultural practices, and a lack of proper conservation management.

The RLBR is one of the areas in Canada with the most heavily modified ecosystems where conservation management such as grazing, clearing, prescribed fire and invasive alien species control is needed in the majority habitats of threatened plants. This can be substantially enhanced by introducing novel conservation approaches, such as establishing Important Plant Areas in the buffer zone and recognising other effective area-based conservation measures in the transition area of the RLBR. These conservation strategies are important for raising public awareness and prompting political actions, but smaller-scale actions are also needed by local conservation practitioners.

OPEN ACCESS

Academic editor:
Kealohanuiopuna Kinney
Received: 8 November 2025
Accepted: 18 February 2026
Published: 13 March 2026

ZooBank: https://zoobank.org/217E6605-16EA-4676-928B-0A8DE72BB82B

Citation: Kricsfalusy V (2026) Conservation of threatened vascular plants in intensive agricultural landscapes in Canada. Nature Conservation 63: 37–57. https://doi.org/10.3897/natureconservation.63.177517

Copyright: © Vladimir Kricsfalusy.
This is an open access article distributed under terms of the Creative Commons Attribution License (Attribution 4.0 International – CC BY 4.0).

Key words: Conservation, distribution, habitats, management strategies, protected areas, rare plants, species hotspots, threats

Introduction

The loss of biodiversity is now considered a major global concern, and some studies suggest that it could rank among the key drivers of ecosystem change in the twenty-first century (Hooper et al. 2012; Ceballos et al. 2015; Díaz et al. 2019; Keck et al. 2025). A recent global assessment estimates that 39% of all vascular plants are threatened with extinction in the wild (Lughadha et al. 2020). To help with conservation planning efforts, a greater understanding of biodiversity is needed at regional scales and for different taxonomic groups (Thuiller et al. 2008; Allan et al. 2022).

Plant species are typically not well represented in conservation planning schemes (Corlett 2016), where faunal groups are commonly used to define key localities and their management priorities (BirdLife International n.d.). Conservation efforts targeting plant diversity are often hampered by lack of suitable data for prioritising conservation action (Kricsfalusy and Trevisan 2014; Darbyshire et al. 2017). Different types of approaches have been developed to assess species based on the type of rarity and the threats to those plants within specific geographic areas. Threatened species have been ranked at different spatial scales: globally, nationally, and regionally by IUCN (2012) and NatureServe (Faber-Langendoen et al. 2012). These methodologies can be used to assign a conservation status rank to a species and develop databases with the occurrence of threatened plants to inform conservation planning.

The first stage of systematic conservation planning prioritizes the compilation of distribution data for threatened plants as they are usually underrepresented when establishing new protected areas (Margules and Pressey 2000). Considering the challenges of managing threatened plants, it is important that land managers rely on accurate data to make informed decisions. There are large gaps in knowledge about the life history, threats, population trends, and habitat requirements needed to recover threatened plants (McCune et al. 2024). Understanding threatened species occurrence and habitat is of particular importance in rapidly developing landscapes (Nielsen et al. 2020). Land clearance and anthropogenic-induced factors such as invasive alien species and altered disturbance regimes impair threatened plants globally (Burgman et al. 2007). In Canada, agriculture was identified as a major cause of habitat loss (Venter et al. 2006). Recent findings by McCune and Morrison (2020) show that land tenure also plays a critical role in those regions where threatened plants are found mostly on private lands. These authors advocate that there is a strong need for Canada to promote stewardship of threatened plants on private lands since they do not benefit from the automatic protection granted under federal programs for species at risk.

A common strategy for enhancing ecological integrity and biodiversity conservation is establishing and managing protected areas which serve as an effective tool to protect biodiversity (Le Saout et al. 2013). Biosphere reserves, launched by the Man and the Biosphere (MAB) Programme of UNESCO in 1970, continuously seek to improve managing their core zones for biodiversity

conservation while responding creatively to the underlying causes of ecosystem destruction by piloting more sustainable land use in transition areas (Stoll-Kleemann and O'Riordan 2017).

The Redberry Lake Biosphere Reserve (RLBR) was designated in 2000 with a main purpose to conserve biodiversity and foster sustainable development (UNESCO n.d.). It is located in the province of Saskatchewan, Canada, on the northern boundary of the Great Plains of North America (Acton et al. 1998). During the last century, vast areas of the privately owned grasslands in Saskatchewan have been cleared and converted to croplands. As a result, the prairie is the most human-altered and fragmented landscape in the province. Current estimates indicate that, on average, less than 20% of original grassland habitats remain in Saskatchewan, and only 9.8% of the province is protected or conserved through various means (Government of Saskatchewan n.d.). Thus, the RLBR plays an important role in safeguarding the future of threatened biodiversity and habitats through protection and sustainable management of the biosphere region.

An analysis of floristic studies in the RLBR has shown scarce information regarding taxonomic composition of rare vascular plants, their distribution, habitat affinities and conservation (Kricsfalusy 2021a, 2023a, 2026; Kricsfalusy and Kindrachuk 2023). This requires conducting a complete inventory of rare plants and their thorough population analysis to identify major threats and develop effective conservation strategies. Carrying out such conservation assessment will help to establish a solid organizational foundation of environmental management in the biosphere region.

Accordingly, the overall objectives of this study are to provide information on threatened vascular plants in the RLBR: (i) taxonomic composition, (ii) spatial distribution, (iii) species hotspots, (iv) population size, (v) habitat affinities, (vi) threats to survival, (vii) conservation status, and (viii) gaps in the current protection. The obtained information is intended to support evidence-based conservation management in the biosphere region.

Methods

Study area

The RLBR is located in one of three prairie provinces of Western Canada (Fig. 1). Since the establishment in 2000, the territory of the biosphere reserve covering 112,000 ha increased five-fold to become a region, and it currently encompasses around 700,000 ha (RLBR n.d.). The RLBR is organized into three interrelated zones known as the core area (52°42'N, 107°10'W), buffer zone, and transition area, which are common for many biosphere reserves. Further, according to The Ecological Land Classification (2018), the RLBR is positioned on the boundary of two biomes – the Prairie and Boreal Plain ecozones – which include the Aspen Parkland and Boreal Transition ecoregions, respectively. The Aspen Parkland ecoregion encompasses four ecodistricts or landscape areas (Hafford Plain, Maymont Plain, Waldheim Plain, and Whitewood Hills) and the Boreal Transition ecoregion includes five ecodistricts (Meeting Lake Upland, Nisbet Plain, Onion Lake Plain, Shellbrook Plain, and Witchekan Plain). Elevation (a.s.l.) across the biosphere region varies from 430 m along the North Saskatchewan River to above 830 m in isolated upland areas (Fig. 1).

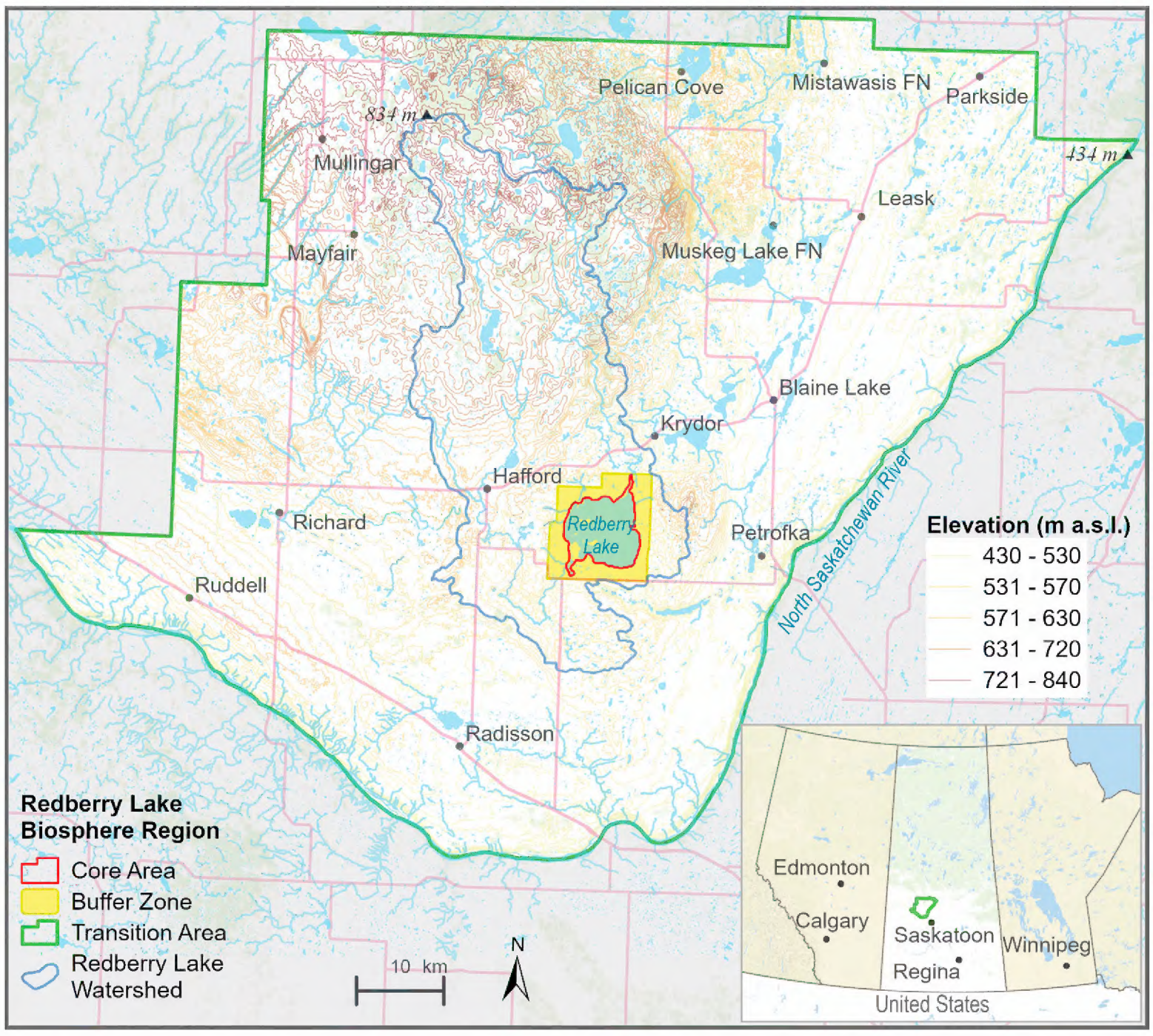

Figure 1. Location of the Redberry Lake Biosphere Region in Canada.

The landscape of the RLBR is composed of rolling prairie dotted with seasonal ponds, marshes and lakes, along with shrub groves, aspen woodlands and boreal forests (Fig. 2). There are patches of natural mixed prairie which are rare in this highly grazed and cultivated prairie. The biosphere region was once very rich in wetlands, which tend to be shallow and saline. Many wetlands were drained and transformed into cultivated croplands and pastures (Whitelaw and Schmutz 2010). Overall, current landcover reflects conversion of natural ecosystems to agriculture. Above 80% of the lands of the region are arable, either under permanent crops (annual and perennial), or under pastures (Acton et al. 1998). Other major land use type is to some extent forested areas in the northern part of the RLBR. There are also smaller types of land use such as residential, recreation, transportation, and commercial.

The climate in the biosphere region is cold and temperate (The Encyclopedia of Saskatchewan 2005), with modest rainfall distributed throughout the year. The mean annual rainfall is 463 mm, with the greatest precipitation in June. Variation in the precipitation during the year (between the driest and wettest months) is 67 mm. While the mean annual temperature has an average of 2.7 °C, the monthly averages fluctuate substantially during the year – from a minimum average of -17.4 °C in January to a maximum average of 24.1 °C in July.

Figure 2. A view of the Redberry Lake Biosphere Region (core area and buffer zone).

Data collection

According to recent studies (Kricsfalusy 2026), the native vascular flora of the biosphere region includes 584 taxa, representing approximately 42.1% of the Saskatchewan's flora. The first list of vascular plants of the RLBR was compiled by local botanist M. Finley in 1999–2009 (Vascular plants of Redberry Lake Biosphere Reserve. Hafford, Canada. [Unpublished data]). This list has not been published, and it is only available as a part of reference herbarium. The author documented 215 native plants, including 10 rare species (*Almutaster pauciflorus*, *Corallorhiza striata* var. *striata*, *Corispermum americanum* var. *americanum*, *Cypripedium parviflorum* var. *pubescens*, *Festuca hallii*, *Gentianopsis virgata* subsp. *macounii*, *Lilium philadelphicum* var. *andinum*, *Liparis loeselii*, *Lomatogonium rotatum* var. *fontanum*, and *Ruppia cirrhosa*). Information on these rare plants is diffuse and doesn't include the data where those species occur.

Data on threatened plants (distribution, habitat affinities, population features and threats to survival) analysed in this study were collected during field surveys conducted in 2010–2025. The obtained data were cross-referenced with information available in literature, databases, and herbarium specimens. Herbarium vouchers of threatened plants deposited at the W.P. Fraser Herbarium (SASK n.d.) in the University of Saskatchewan were examined. Identified locations were verified against the records at the Virtual Herbarium of Plants at Risk in Saskatchewan (VHPRSK n.d.) and the Hunting, Angling and Biodiversity Information of Saskatchewan (HABISask n.d.) database. Nomenclature of the taxa follows the Database of Vascular Plants of Canada or VASCAN (Brouillet et al. 2010). The species ranking follows the NatureServe categories (NatureServe n.d.) and the latest listing by the Saskatchewan Conservation Data Centre (SKCDC n.d.).

All study plants were identified *in situ* and a few photos for each species observed were taken. Species occurrences were georeferenced using a GPS unit (Garmin Oregon 650t) with an accuracy of 2 m following guidelines for plant mapping developed by the Saskatchewan Conservation Data Centre (SKCDC 2016). An individual plant, or plants that occur together in a relatively small area (a patch size of < 5 m radius) were recorded with a single waypoint in the centre of the patch. Plants that are > 30 m apart were mapped as separate occurrences. Distinct locations (sites) were identified applying a threshold of 1 km. The distribution of threatened species is depicted on a map with dots, where each dot represents an occurrence of individual species and on a map with 2 km × 2 km grid cells, where each cell represents the number of different species in that unit or species richness.

Whenever possible, the number of individuals were either counted directly (for the least distributed species) or estimated from partial counts (for species located at discontinuous sites). To characterize the habitat for each population, the corresponding inventories of the vegetation communities were made together with an assessment of the fragility of the habitat, state of conservation, disturbance risks and agents, etc. Detailed habitat classification is presented in a separate paper (Kricsfalusy 2026). The following habitat types were identified: open and shallow water, wetland (marsh, fen, swamp, and bog), riparian, grassland, shrubland, woodland, forest, sandy, saline and man-made (ruderal, agricultural, and cultivated). Vegetation types were identified using the principles of the Ecological Land Classification for southern Ontario (Lee et al. 1998), adapted for Saskatchewan. Soil data were retrieved from Saskatchewan Soil Information System (SKSIS n.d.) and verified during field surveys.

Results and discussion

Taxonomic composition

The intensive field studies allowed identification of 46 threatened plant taxa (31 species, 5 subspecies and 10 varieties) which belong to 19 families and 34 genera (Suppl. material 1: table S1, Fig. 3). The majority of threatened plants (36 taxa, 78.3%) were found at the RLBR for the first time. One rare species – *Lemna minor* which was earlier indicated for the region by M. Finley – has not been included in this list after a critical analysis and evaluation of existing herbarium samples (Kricsfalusy 2021a). These 46 threatened plant taxa attest for approximately 7.9% of the native flora of the biosphere region and 8.6% of all rare vascular plants listed for the province by the Saskatchewan Conservation Data Centre (SKCDC n.d.).

In terms of the species richness, top families are Orchidaceae (9 taxa), Cyperaceae (8), and Poaceae (4), followed by Asteraceae, Gentianaceae, and Rosaceae with three taxa each (Table 1, Fig. 4A). The next three families (Amaranthaceae, Hydrocharitaceae, and Scrophulariaceae) contain two taxa each. Together, these top families include 36 taxa or 78.3% of all threatened plants, and each of the rest 10 families include one taxon only. Among the richest plant genera, the dominant place is occupied by *Carex* (4 taxa), *Cypripedium* (3), and *Potentilla* (3), followed by five genera (*Corispermum*,

Figure 3. Some threatened plants of the Redberry Lake Biosphere Region: **A.** *Almutaster pauciflorus*; **B.** *Botrychium campestre* var. *campestre*; **C.** *Festuca hallii*; **D.** *Cypripedium parviflorum* var. *pubescens*; **E.** *Cypripedium parviflorum* var. *makasin*; **F.** *Corallorhiza striata* var. *striata*; **G.** *Gentianopsis virgata* subsp. *macounii*; **H.** *Lomatogonium rotatum* var. *fontanum*; **I.** *Viola pedatifida*. (Photos: V. Kricsfalusy).

Gentianopsis, *Pedicularis*, *Platanthera*, and *Rhynchospora*) each containing two taxa (Table 1). Together, these top genera include 20 taxa or 43.5% of all threatened plants (Fig. 4B). Finally, 26 genera contain one taxon only.

Table 1. List of largest families and genera of the threatened flora of the Redberry Lake Biosphere Region. The highlighted in bold number (3) differs significantly from other observations.

Family	Number of species	Number of genera	Ratio of species per genus	Family	Genus	Number of species
Orchidaceae	9	6	1.5	Cyperaceae	*Carex*	4
Cyperaceae	8	4	2	Orchidaceae	*Cypripedium*	3
Poaceae	4	4	1	Rosaceae	*Potentilla*	3
Asteraceae	3	3	1	Amaranthaceae	*Corispermum*	2
Gentianaceae	3	2	1.5	Gentianaceae	*Gentianopsis*	2
Rosaceae	3	1	**3**	Scrophulariaceae	*Pedicularis*	2
Hydrocharitaceae	2	2	1	Orchidaceae	*Platanthera*	2
Amaranthaceae	2	1	2	Cyperaceae	*Rhynchospora*	2
Scrophulariaceae	2	1	2			
Total	**36**	**24**		**Total**		**20**

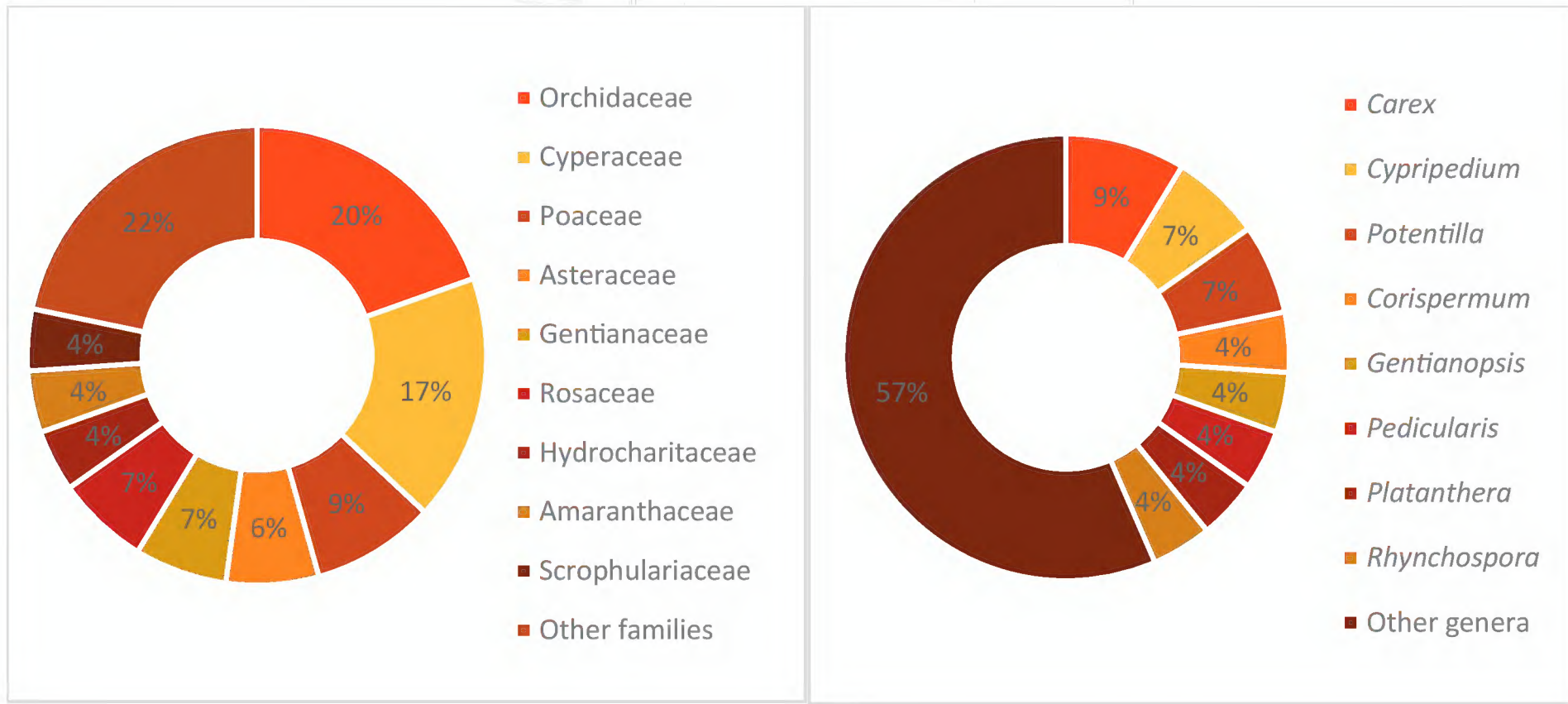

Figure 4. The most represented families (**A**) and genera (**B**) of threatened plants in the flora of the Redberry Lake Biosphere Region.

Spatial distribution

The spatial analysis revealed that threatened plants are unevenly distributed across both the Prairie and Boreal Plain ecozones. The variability in threatened plants occurrences and species richness across these ecozones within the Aspen Parkland and Boreal Transition ecoregions is shown in Fig. 5A, B.

Among the ecodistricts under the Aspen Parkland ecoregion, the Hafford Plain had the highest number of species occurrences (1 to 20) with the median of 7.65 ± 7.73, representing 153 records across 20 species. This was followed by the Whitewood Hills with 1 to 13 occurrences and the median of 3.52 ± 3.78, where 81 records were observed across 23 species. The Waldheim Plain showed the lower number of occurrences (1 to 5) with the median 2.14 ± 1.68, and 15 records across 7 species. The Maymont Plain had the least, with only 3 records across 3 species.

In the Boreal Plain ecoregion, threatened plants were less frequent. Among five ecodistricts of this ecoregion, the Witchekan Plain showed the highest

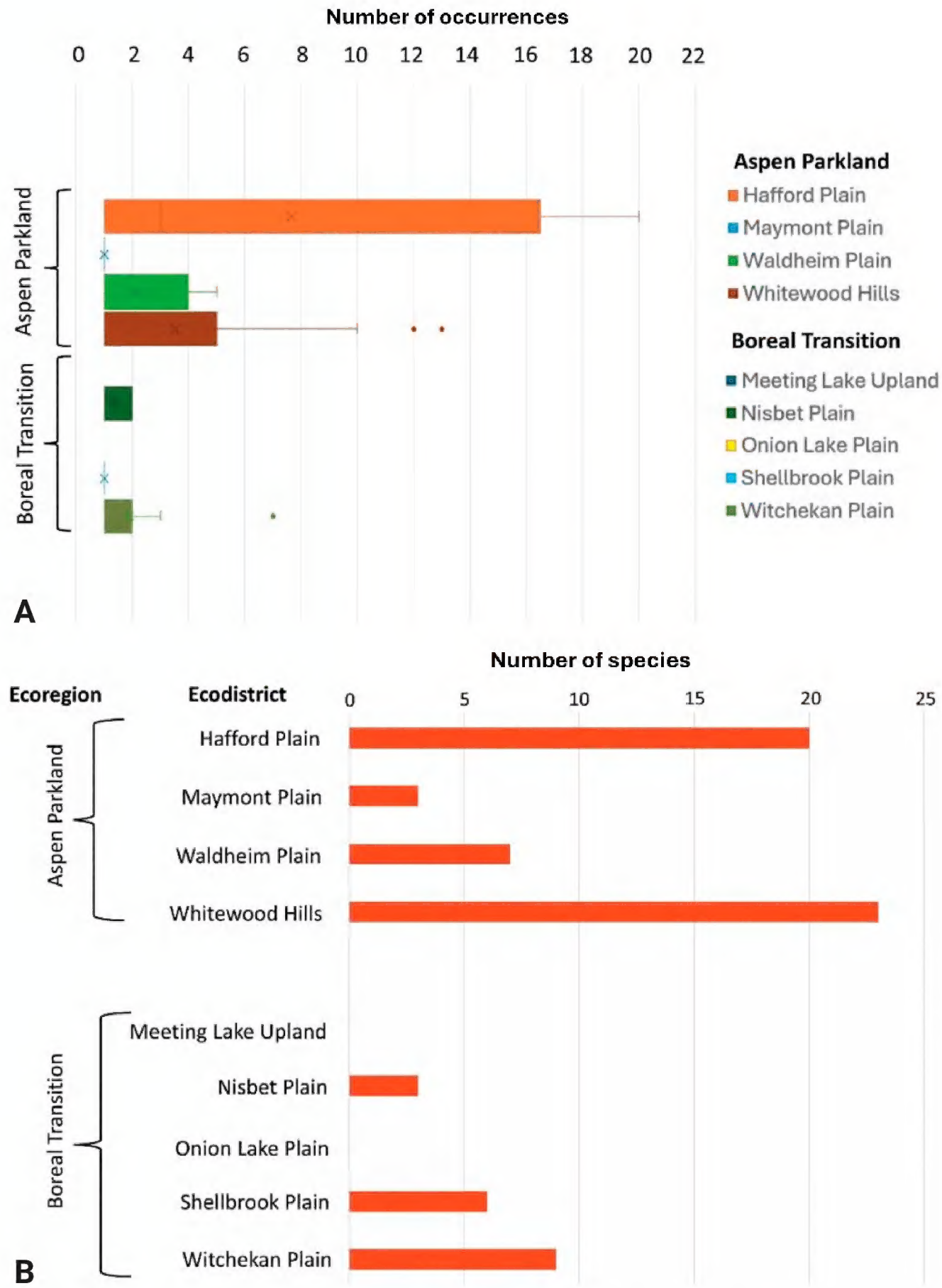

Figure 5. Distribution of threatened plants across the major ecosystems of the Redberry Lake Biosphere Region: **A.** box plot of species occurrences depicting the median, minimum and maximum range; **B.** bar chart of species richness.

presence of 9 species, with 17 occurrences that vary from 1 to 7, the median 1.89 ± 2.03. In the Nisbet Plain 4 occurrences across 3 species were documented, with the number of occurrences 1 to 2, and the median 1.33 ± 0.58. The Shellbrook Plain had only a single occurrence record across 6 species. No species were recorded in the Meeting Lake Upland and Onion Lake Plain.

Species richness hotspots

The field work carried out for this study allowed to substantially enlarge the number of threatened plant species (from 10 to 46) and their occurrences (from 10 to 279). Out of a total of 1917 grids of 2 × 2 km that make up the RLBR, threatened plants were recorded only in 52 of them (2.7% of all grid cells).

The study revealed that most threatened plants have very narrow area within the biosphere region. The majority of species (34, 73.9%) have the low number of occurrences (1–5), group with the moderate number of occurrences (6–25) includes eight species (17.4%), and there are only four species (8.7%) with the high number of occurrences (26–50). Thus, the number of occurrences per threatened species is skewed toward the small distribution classes. When assessing the number of occupied grids per threatened species, which can be considered as Area of Occupancy (AOO), a similarly skewed pattern emerged. The majority of species (36, 78.3%) were recorded in 1–3 grid cells, eight species (17.4%) in 5–8 and only two species (4.3%) in 11–13 grid cells.

The most represented species – *Cypripedium parviflorum* var. *pubescens* (32 occurrences, 13 grid cells) and *Almutaster pauciflorus* (30 occurrences, 12 grid cells) – have the largest number of both allocations (32.1% of occurrences and 49.1% of grids, respectively). The second most represented group includes three species which also have the large number of occurrences, but they are concentrated in the small number of grids: *Liparis loeselii* (29 occurrences, 7 grid cells), *Festuca hallii* (27, 8), and *Gentianopsis virgata* subsp. *macounii* (25, 6). Given that majority of threatened plants occur in a few sites, their survival depends solely on the known individuals, and they are under high threats of local extinction. Although some threatened species recorded in the larger number of sites, their populations are very dispersed, with rather low number of individual plants and as such are vulnerable to stochastic events.

Within 52 occupied grids, a total of 279 occurrences of 46 species were documented, indicating localized zones of threatened plants amidst a largely unoccupied matrix (1865 grids, 97.3%). Species richness per grid cell revealed a highly uneven distribution (Fig. 6) similarly skewed toward the small classes. The majority of occupied grid cells (39, 75.0%) are species-poor hosting 1–3 species. A much smaller proportion of grid cells (11, 21.2%) supports moderate richness (4–7 species). The highest richness (8–9 species) was recorded in two (3.8%) grid cells only. These grids represent significant species hotspots and may reflect a unique combination of habitat conditions suitable for multiple threatened plants.

The conducted analysis allowed identification of seven richness hotspots with more than five threatened species each (Fig. 6). It was found that four hotspots – sites Flats (8 species), Regional Park (6), Marshy Creek (5), and Bible Camp (5) – are in the buffer zone of the RLBR. Another three hotspots – sites Muskeg Lake (10 species), Martins Lake (5), and Borden Dunes (5) – are in the transition area of the biosphere region. It is a matter of concern that three out of seven hotspots are found outside of the core area and buffer zone of the RLBR which are designated for biodiversity protection.

Population size

The number of individuals per threatened species is hard to estimate since it significantly varies across different locations. It was found that most threatened plants are characterized by small populations with sporadic or scattered-diffuse spatial distribution of individuals, as well as a relatively low projection cover (up to 3–5%). On average, the population size is skewed toward the small classes (1–5 and 6–11 individuals), while only seven species contain

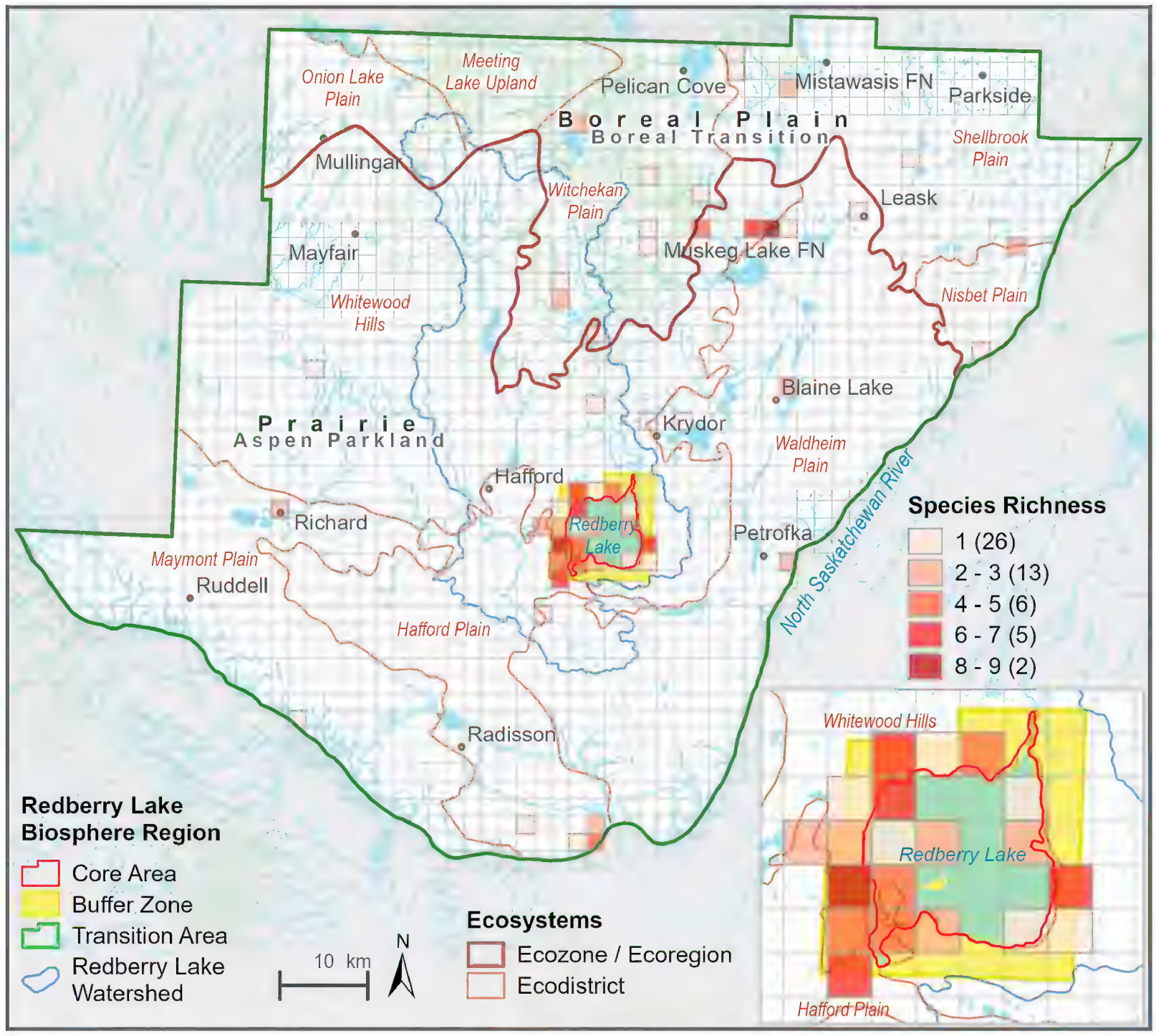

Figure 6. The distribution and hotspots of threatened plants in the Redberry Lake Biosphere Region.

51–100 individuals. *Botrychium campestre* var. *campestre* is the only threatened plant with one recorded individual (Kricsfalusy 2021b). This population occurs at the northern limit of the species' North American range. On the other hand, *Festuca hallii* is frequently found in large patches (>1,000 individuals), although in some instances it can be smaller (51–100 individuals).

Small population size is often the consequence of recent habitat loss due to human activities, but it can also be the way of life for some highly specialized organisms restricted to patchy and scarce habitats. The decline of these remnants may be difficult to detect. In absence of the necessary long-term monitoring, our ability to assess the vulnerability of populations of threatened plants will be enhanced if important information like the history of land use, species ecology, and the life span are considered. Hence, critically imperiled plants found in isolated locations (S1– 2 taxa), as well as imperiled species (S2– 7), deserve special attention. Their small size populations can be marked by various structural and functional disorders: incomplete age spectra, limited potential for self-renewal (vegetatively or generatively) and low viability. Therefore, the population data should be continually updated, and long-term monitoring plots must be established for the rarest species. Monitoring known populations of threatened plants would help to determine whether they are spreading or declining. This information will serve to designate the future priorities for the conservation of threatened plants in the biosphere region.

Growth form and habitat affinity

The obtained results indicate that in terms of plant growth form (Fig. 7A), threatened species belong mostly to herbs (29 taxa, 63%) and graminoids (13, 28.3%). Together, these groups include 42 taxa (91.3%). The other two groups include aquatic herbs (3 taxa, 6.5%) and ferns and fern allies (1, 2.2%). Trees, shrubs, and vines are not present among threatened plants. Overall, herbaceous and graminoid species dominate the life spectrum of threatened plants, while other growth forms include just a few species, and trees, shrubs and vines are completely absent.

Analysis of habitat affinities of threatened plants show that they occur in a diverse range of habitat types. Almost half of all threatened plants (21 species, 45.7%) are found in wetlands (moderate-rich fens, marshes and wet meadows). Grassland (6 species), sandy (6), and woodland (5) habitats together account for 17 species (40.0%). The rest of the four habitat types contain 9 species (19.6%). Habitat affinities of threatened plants are shown in Fig. 7B. Given substantially smaller portion of the landscape occupied by wetland habitats, a proportion of threatened plants that occur here is much higher than in grasslands which are dominate type of vegetation. Threatened grassland plants (6 species, 13%) have upland affinities and occur on dry ridges in rolling prairie.

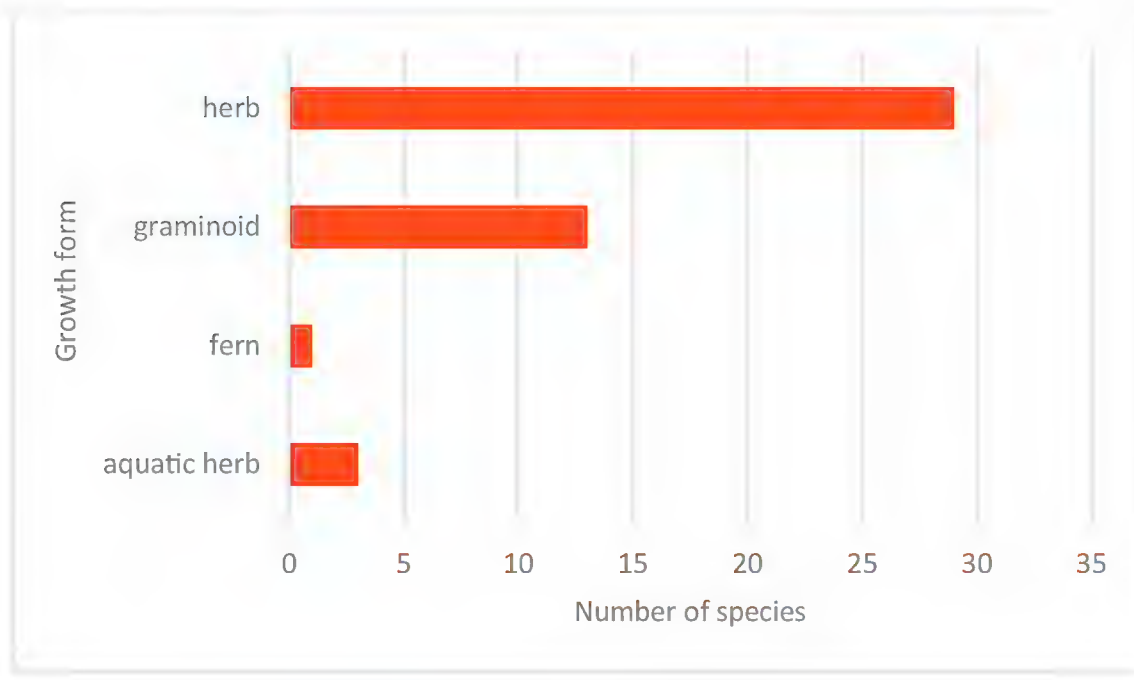

Figure 7. Distribution of threatened plants per growth forms (**A**) and habitat types (**B**) in the Redberry Lake Biosphere Region.

The same number of threatened plants (6 species, 13%) seek refuge in sandy habitats. Woodland patches dominated by different poplar species (*Populus balsamifera* and *P. tremuloides*) are also among the important habitat types providing home for five species (10.9%). Two other habitat types – forests and open waters – support a unique set of species, holding the equal number of threatened plants (3 species, 6.5% each). The lowest number of threatened plants (2 species, 4.3%) is found in saline habitats.

Our results concerning habitat affinities show that threatened plants are more likely to be associated with wetlands than dry, open habitats (grasslands and sandy sites). This association between threatened plants and different habitats may be explained by local natural history. This part of Saskatchewan has been subject to intense agricultural pressure which resulted in extensive habitat alteration. Due to the dramatic transition from natural to agricultural ecosystems, most of the native prairie has been wiped out. To preserve threatened plants, it is important to know where they occur and what aspects of their biology and habitats most limit persistence.

Main threats

Owing to the steadily shrinking area of natural landscape in the biosphere region, habitat loss, successional overgrowth, the spread of invasive species, and wetland interventions have emerged as great problems. The majority of threatened plants are affected by one or two threats, whereas *Cypripedium parviflorum* var. *pubescens* is in the most extreme situation, facing four threats. It was found that only a few rare plants (4 species, 8.7%) were not under any imminent threat.

The two most severe threats estimated to face rare plants are habitat loss and successional overgrowth; the combined impact of which affects 22 species (47.8%) (Fig. 8A). Habitats of *Cypripedium parviflorum* var. *pubescens*, *Botrychium campestre* var. *campestre*, and *Corallorhiza striata* var. *striata* are particularly vulnerable to the encroachment of woody species during natural succession. When these habitats begin to resemble a woodland with closed canopy, the populations of these plant species may disappear.

The detrimental effects of invasive alien species (IAS) on the growth and survival of eight threatened plants (17.4%) were also observed. Many of these IAS have become introduced with seed crops, livestock feed, or brought here for use as forage crops or for planting shelterbelts (Kricsfalusy 2023b). IAS continue to spread, especially through roadsides and newly disturbed areas. This process will probably increase in the future due to climate change, which may influence the patterns of invasion and the response of the native flora. To accomplish effective control of IAS, it is necessary to monitor and survey the infested areas in order to document change in their status and results of any management methods. Rather than focusing on specific IAS that require control, it might be more effective to concentrate on certain habitats or threatened species that are at greatest risk.

Less common, but also considerable threats are habitat destruction due to wetland interventions and recreational land use for cottages and public facilities (each threat targets 6 species, 13%). It was shown that excessive wetland interventions may distort the habitat by accelerating the invasion of competitive species, reorganizing the level of spatial heterogeneity, diminishing seed

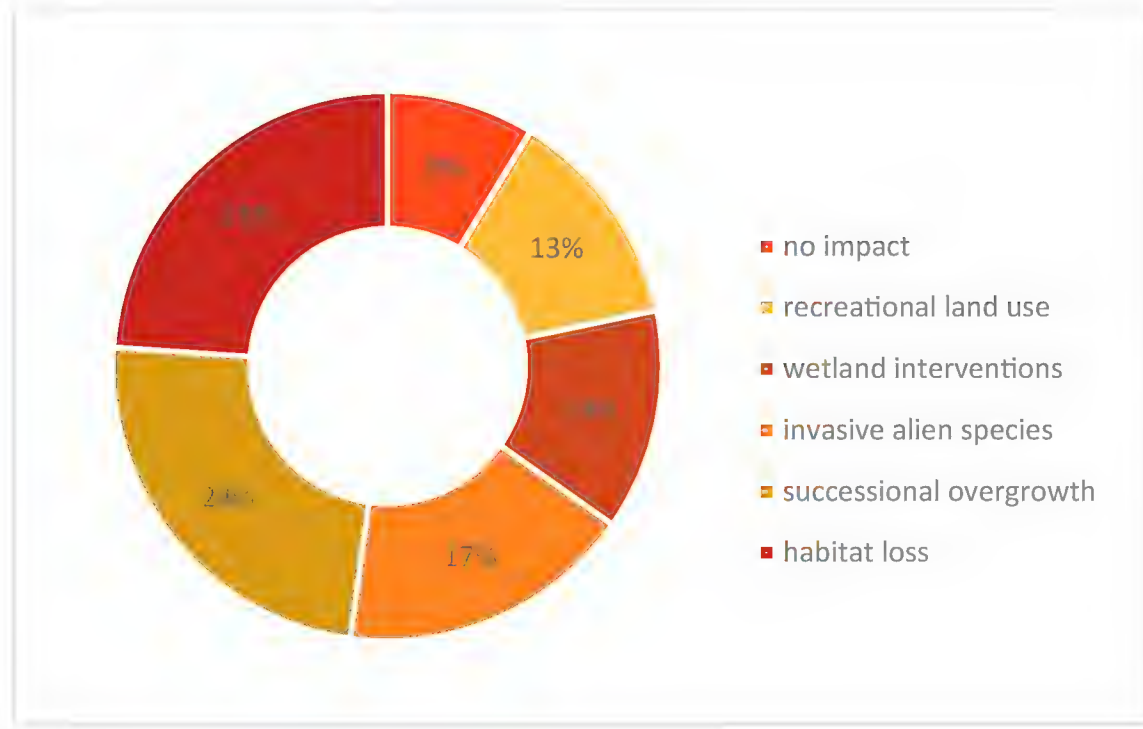

Figure 8. Most common threats affecting rare plants (**A**) and species distribution per subnational (provincial) conservation ranks (**B**) in the Redberry Lake Biosphere Region: S1– Critically Imperiled/Extremely rare, S2– Imperiled/Very rare, S3– Vulnerable/Rare to uncommon.

bank, reducing survival rate of remaining population, and altering hydrological regime and nutrient availability (Schweiger et al. 2016).

Thus, introducing modern agricultural practices may help to lessen the impact of industrial farming on the environment by reducing the harmful effects posed by the biggest stressors. Most of the mentioned threats are resulting from land use history, current unsustainable agricultural practices and a lack of proper conservation management. Avoiding massive land clearing for growing crops which requires the removal of native cover – including trees, bushes and herbaceous vegetation – and opting for less invasive agricultural practices, controlled burning and grazing could provide an effective tool to ensure suitable habitat conditions and improve the viability of threatened plants.

Conservation status

The conservation ranks of each threatened species were assigned according to the Saskatchewan Conservation Data Centre (SKCDC n.d.) and

cross-referenced with NatureServe (n.d.). It should be noted that the same species can be placed in all three categories (global, national, and subnational) simultaneously. The conducted analysis shows (Suppl. material 1: table S1) that two species are ranked at the global level (G3) and five species at the national level (N3). At the subnational (provincial) level the following ranking is provided (Fig. 8B): S1– 2 taxa, S2– 7, and S3– 37. As we can see, group of imperiled species (S1 and S2) includes nine taxa (19.6%), and the vast majority of threatened plants (37, 80.4%) fall under the category S3– Vulnerable species at moderate risk of extirpation.

Additionally, *Cypripedium passerinum* and *Liparis loeselii* assessed as S3 species at moderate risk of extirpation by NatureServe (n.d.) are simultaneously categorised by IUCN (n.d.) as VU– Vulnerable and NT– Near Threatened, respectively. It is rather unexpected that two uncommon species (*Fraxinus pennsylvanica* and *Ulmus americana*) assessed as S4– Apparently Secure by NatureServe, according to IUCN are ranked as CR– Critically Endangered and EN– Endangered, respectively.

Territorial protection

To identify gaps in territorial protection of threatened plants, occurrences of each species were overlaid with the zoning system of the RLBR. It was found that the core area holds 64 occurrences of 12 species, the buffer zone has 156 occurrences of 19 species, and the transition area contains 123 occurrences of 35 species. As we can see, the total number of species occurrences in the core area and buffer zone (220) is much higher than in the transition area (123). However, in terms of species richness, there are more threatened plants located in the transition area (35 species) than in the core area and the buffer zone combined (31).

Those species located in the transition area are vulnerable to such threats as habitat fragmentation, increased disturbance regime due to agricultural intensification, recreational land use, and resource extraction. The realization of conservation goals requires strategies for managing whole landscapes including areas allocated to both production and protection. Therefore, land managers have to employ threatened plants occurrence data to assess species distribution across multiple scales within the biosphere region to prioritize their population monitoring and adopt existing beneficial management practices. Conservation management such as grazing, clearing, prescribed burn and invasive alien species control is needed in the majority of threatened species habitats.

It is a matter of concern that the core area and the buffer zone of the RLBR designed for conserving biological diversity holds together less threatened species than the transition area alone. The territorial protection in the biosphere region can be improved by creating Important Plant Areas (Plantlife International 2018) to safeguard the calcareous fens and meadow marshes in the buffer zone of the RLBR (Kricsfalusy et al. in press). Furthermore, as shown by Maxwell et al. (2020), other effective area-based conservation measures (OECMs) can deliver effective biodiversity conservation and should be extended and diversify. This approach can be effectively implemented in the transition area of the RLBR along with establishing micro-reserves and small-scale plant-protected areas.

Conclusion

The conducted study allowed to identify 46 vascular plants (31 species, 5 subspecies and 10 varieties) of conservation concern in the biosphere region. Field investigations documented threatened plants distribution across the Prairie and Boreal Plain ecozones and species affinities with major habitat types, including within the newly acquired areas of the RLBR which remain unexplored botanically. It was found that the majority of threatened plants occurrences and species richness are concentrated in the Aspen Parkland ecoregion (Hafford Plain and Whitewood Hills ecodistricts) of the Prairie ecozone.

The study revealed that most threatened plants have very narrow distribution and low number of occurrences in the RLBR. Given that the majority of threatened species occur in a few sites and their survival depends solely on the small population size they are under high threat of local extinction. Although some threatened species were recorded in the larger number of sites, their populations are very dispersed, with rather low number of individuals and as such are vulnerable to stochastic events. The conducted analysis allowed identification of seven richness hotspots with 5–10 threatened species each. It is a matter of concern that three out of seven hotspots are outside of the core area and the buffer zone of the RLBR which are designated for biodiversity protection.

The conservation ranks of each threatened species were determined, and their protection status was assessed. The conducted analysis indicates insufficient data regarding many threatened plants, which are necessary for the development of priority conservation measures. Therefore, chorological and population studies of threatened plants remain relevant, primarily concerning the regular monitoring of nine imperiled species (S1 and S2). The obtained results will serve as the basis for establishing biodiversity monitoring and improving conservation management at the regional level.

Owing to the steadily shrinking area of natural landscape in the biosphere region, habitat loss, successional overgrowth, spread of invasive alien species and wetland interventions are becoming the main threats for rare plants. Most of these threats are resulting from land use history, current unsustainable agricultural practices, and a lack of proper conservation management. The different threats faced by rare plants can be averted by different means of restoration, with the most relevant being the clearing of bushes and trees, restorative practices, and control of invasive alien species. In addition, introduction of conservation grazing and controlled burning should be investigated in certain sites, as it is ultimately one of the few means to ensure the long-term persistence of some threatened plants. Thus, introducing modern agricultural practices may help to lessen the impact of industrial farming on the environment by reducing the harmful effects posed by the biggest stressors.

The gap analysis has shown that the core area and the buffer zone of the RLBR holds together less threatened plant species than the transition area, which is intended for sustainable use of natural resources and not biodiversity conservation. Consequently, land management in the transition area needs to include new sites for biodiversity conservation in addition to places where resource extraction may continue (under restrictions and

improved standards). It could be achieved through extending the existing buffer zone of the RLBR and creating the additional core area in the newly acquired territory in the Boreal Plain ecozone. This can be substantially enhanced by introducing novel conservation approaches, such as establishing Important Plant Areas (IPAs) and recognizing other effective area-based conservation measures (OECMs), as well as culture change within the conservation community. These conservation strategies are important for raising public awareness and prompting political actions, but smaller-scale actions are also needed by local conservation practitioners.

Acknowledgements

I am grateful to students in the School of Environment and Sustainability at the University of Saskatchewan for technical help with field surveys. Sadik Enan assisted with data management. Denver Falconer provided guidance with plant collections at the W.P. Fraser Herbarium. Tayyab Shah, Canadian Hub for Applied and Social Research, created GIS maps.

I thank John Kindrachuk, Director of Strategic Partnerships at the Redberry Lake Biosphere Region, for his support with organizing my field visits. I recognize the keen interest of the residents of the biosphere region and appreciate granting access to their land for the field surveys. I also thank members of Mistawasis Nêhiyawak First Nation and Muskeg Lake Cree Nation for sharing their knowledge and help with accessing remote areas.

Additional information

Conflict of interest

The author has declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Use of AI

No use of AI was reported.

Funding

This research was partially supported by the Shyluk Nature's Health Fund (#428371) at the University of Saskatchewan in 2024–2025.

Author contributions

The author solely contributed to this work.

Author ORCIDs

Vladimir Kricsfalusy https://orcid.org/0000-0002-1340-1490

Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

References

Acton DF, Padbury GA, Stushnoff CT (1998) The ecoregions of Saskatchewan. Canadian Plains Research Center, University of Regina Press, Regina, Canada, 205 pp.

Allan JR, Possingham HP, Atkinson SC, Waldron A, Di Marco M, Butchart SHM, Adams ZVM, Kissling WD, Worsdell T, Sandbrook C, Gibbon G, Kumar K, Mehta P, Maron M, Williams BA, Jones KR, Wintle BA, Reside AE, Watson JEM (2022) The minimum land area requiring conservation attention to safeguard biodiversity. Science 376(6597): 1094–1101. https://doi.org/10.1126/science.abl9127

BirdLife International (n.d.) BirdLife International. https://www.birdlife.org/our-science/ [Accessed 21 November 2024]

Brouillet L, Desmet P, Coursol F, Meades SJ, Favreau M, Anions M, Bélisle P, Gendreau C, Shorthouse D (2010) VASCAN, the database of vascular plants of Canada. http://data.canadensys.net/vascan/ [Accessed 19 February 2024]

Burgman MA, Keith D, Hopper SD, Widyatmoko D, Drill C (2007) Threat syndromes and conservation of the Australian flora. Biological Conservation 134(1): 73–82. https://doi.org/10.1016/j.biocon.2006.08.005

Ceballos G, Ehrlich PR, Barnosky AD, García A, Pringle RM, Palmer TM (2015) Accelerated modern human-induced species losses: Entering the sixth mass extinction. Science Advances 1: e1400253. https://doi.org/10.1126/sciadv.1400253

Corlett RT (2016) Plant diversity in a changing world: Status, trends, and conservation needs. Plant Diversity 38(1): 10–16. https://doi.org/10.1016/j.pld.2016.01.001

Darbyshire I, Anderson S, Asatryan A, Byfield A, Cheek M, Clubbe C, Ghrabi Z, Harris T, Heatubun CD, Kalema J, Magassouba S, McCarthy B, Milliken W, de Montmollin B, Lughadha EN, Onana J-M, Saïdou D, Sârbu A, Shrestha K, Radford EA (2017) Important Plant Areas: Revised selection criteria for a global approach to plant conservation. Biodiversity and Conservation 26: 1767–1800. https://doi.org/10.1007/s10531-017-1336-6

Díaz SM, Settele J, Brondízio E, Ngo H, Guèze M, Agard J, Arneth A, Balvanera P, Brauman K, Butchart S, Chan K, Garibaldi LA, Ichii K, Liu J, Subramanian SM, Midgley GF, Miloslavich P, Molnár Z, Obura D, Pfaff A, Polasky S, Purvis A, Razzaque J, Reyers B, Chowdhury RR, Shin Y-J, Visseren-Hamakers I, Willis K, Zayas C (2019) The global assessment report on biodiversity and ecosystem services: Summary for policy makers. IPBES Secretariat, Bonn, Germany, 60 pp.

Faber-Langendoen DJ, Nichols L, Master K, Snow K, Tomaino A, Bittman R, Hammerson G, Heidel B, Ramsay L, Teucher A, Young B (2012) NatureServe conservation status assessments: methodology for assigning ranks. NatureServe, Arlington, Virginia, 52 pp.

Government of Saskatchewan (n.d.) Protected and Conserved Areas Network (PCAN). https://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/land-management/protected-and-conserved-areas-network [Accessed 9 February 2026]

HABISask (n.d.) The Hunting, Angling and Biodiversity Information of Saskatchewan. Government of Saskatchewan. https://gisappl.saskatchewan.ca/Html5Ext/?viewer=habisask [Accessed 19 February 2024]

Hooper DU, Adair EC, Cardinale BJ, Byrnes JE, Hungate BA, Matulich KL, Gonzalez A, Duffy JE, Gamfeldt L, O'Connor MI (2012) A global synthesis reveals biodiversity loss as a major driver of ecosystem change. Nature 486(7401): 105–108. https://doi.org/10.1038/nature11118

IUCN (2012) International Union for Conservation of Nature. Guidelines for application of IUCN Red List criteria at regional and national levels. Version 4.0. IUCN, Gland/Cambridge, 41 pp.

IUCN (n.d.) International Union for Conservation of Nature. The IUCN Red List of threatened species. Version 2025-2. https://www.iucnredlist.org [Accessed 11 August 2025]

Keck F, Peller T, Alther R, Barouillet C, Blackman R, Capo E, Chonova T, Couton M, Fehlinger L, Kirschner D, Knüsel M, Muneret L, Oester R, Tapolczai K, Zhang H, Altermattet F (2025) The global human impact on biodiversity. Nature 641 395–400. https://doi.org/10.1038/s41586-025-08752-2

Kricsfalusy V (2021a) Rare vascular plants of Redberry Lake Biosphere Reserve. Blue Jay 79(4): 10–17. https://doi.org/10.29173/bluejay6335

Kricsfalusy V (2021b) Distribution, habitat affinities, and conservation of *Botrychium campestre* (Ophioglossaceae) on its northern range limit. Western North American Naturalist 81(4): 529–543. https://doi.org/10.3398/064.081.0405

Kricsfalusy V (2023a) New rare vascular plants for Redberry Lake Biosphere Reserve. Blue Jay 81(1): 19–24. https://doi.org/10.29173/bluejay6362

Kricsfalusy V (2023b) The non-native flora of Redberry Lake Biosphere Reserve, Canada. Thaiszia – Journal of Botany 33(1): 45–61. https://doi.org/10.33542/TJB2023-1-03

Kricsfalusy V (2026) The native flora of the Redberry Lake Biosphere Region (Saskatchewan, Canada): Taxonomy, biogeography, habitats, and conservation. Nordic Journal of Botany 04865. https://doi.org/10.1002/njb.04865

Kricsfalusy V, Kindrachuk J (2023) Orchids of the Redberry Lake Biosphere Region: Diversity, distribution, habitats and conservation. Blue Jay 81(3): 11–21. https://doi.org/10.29173/bluejay6376

Kricsfalusy V, Trevisan N (2014) Prioritizing regionally rare plant species for conservation using herbarium data. Biodiversity and Conservation 23: 39–61. https://doi.org/10.1007/s10531-013-0583-4

Kricsfalusy VV, Enan MDS, Jonson A, Osei P, Stittrich F, Ulrich K (in press) A proposed Important Plant Areas (IPA) as a tool for conserving threatened plants and habitats in the Redberry Lake Biosphere Region, Saskatchewan. The Canadian Field-Naturalist.

Le Saout S, Hoffmann M, Shi Y, Hughes A, Bernard C, Brooks TM, Bertzky B, Butchart SHM, Stuart SN, Badman T, Rodrigues ASL (2013) Protected areas and effective biodiversity conservation. Science 342: 803–805. https://doi.org/10.1126/science.1239268

Lee H, Bakowsky W, Riley J, Bowles J, Puddister M, Uhlig P, McMurray S (1998) Ecological Land Classification for southern Ontario: First approximation and its application. Southcentral Science Section, Ontario Ministry of Natural Resources, North Bay, Canada, 225 pp.

Lughadha EN, Bachman SP, Leão TCC, Forest F, Halley JM, Moat J, Acedo C, Bacon KL, Brewer RFA, Gâteblé G, Gonçalves SC, Govaerts R, Hollingsworth PH, Krisai-Greilhuber I, de Lirio EJ, Moore PGP, Negrão R, Onana JM, Rajaovelona LR, Razanajatovo H, Reich PB, Richards SL, Rivers MC, Cooper A, Iganci J, Lewis JP, Smidt EC, Antonelli A, Mueller GM, Walkeret BE (2020) Extinction risk and threats to plants and fungi. Plants, People, Planet 25: 389–408. https://doi.org/10.1002/ppp3.10146

Margules CR, Pressey RL (2000) Systematic conservation planning. Nature 405: 243–253. https://doi.org/10.1038/35012251

Maxwell SL, Cazalis V, Dudley N, Hoffmann M, Rodrigues AS, Stolton S, Visconti P, Woodley S, Kingston N, Lewis E, Maron M, Strassburg BBN, Wenger A, Jonas HD, Venter

O, Watson JEM (2020) Area-based conservation in the twenty-first century. Nature 586(7828): 217–227. https://doi.org/10.1038/s41586-020-2773-z

McCune JL, Baldwin SJ, Bennett JR, Husband BC, Joly S, Kraus D, Lamb EC, Vamosi JC, Van Natto AC, Whitton J (2024) The state of plant conservation in Canada: a survey of practitioners. FACETS 9: 1–13. https://www.facetsjournal.com/doi/full/10.1139/facets-2023-0216

McCune JL, Morrison PDS (2020) Conserving plant species at risk in Canada: Land tenure, threats, and representation in federal programs. FACETS 5: 538–550. https://doi.org/10.1139/facets-2019-0014

NatureServe (n.d.) Biodiversity Location Data. NatureServe Explorer. https://explorer.natureserve.org/ [Accessed 30 May 2022]

Nielsen SE, Dennett JM, Bater CW (2020) Landscape patterns of rare vascular plants in the Lower Athabasca Region of Alberta, Canada. Forests 11(6): 699. https://doi.org/10.3390/f11060699

Plantlife International (2018) Identifying and conserving Important Plant Areas (IPAs) around the world: A guide for botanists, conservationists, site managers, community groups and policy makers. Plantlife, Salisbury, 37 pp.

RLBR (n.d.) Redberry Lake Biosphere Region. http://redberrylake.ca/ [Accessed 15 January 2024]

SASK (n.d.) W.P. Fraser Herbarium at the University of Saskatchewan. https://agbio.usask.ca/fraser-herbarium/index.php [Accessed 12 November 2024]

Schweiger EW, Grace JB, Cooper D, Bobowski B, Briten M (2016) Using structural equation modeling to link human activities to wetland ecological integrity. Ecosphere 7: e01548. https://doi.org/10.1002/ecs2.1548

SKCDC (2016) Saskatchewan Conservation Data Centre. SKCDC guidelines for collecting spatial data during vascular plant surveys. Ministry of Environment, Regina, Canada, 11 pp.

SKCDC (n.d.) Saskatchewan Conservation Data Centre. Species list: Vascular plants. Version 30 April 2025. www.biodiversity.sk.ca/SppList.htm [Accessed 21 June 2025]

SKSIS (n.d.) Saskatchewan Soil Information System. SKSIS Working Group. Eds. Bedard-Haughn A et al. https://app.sksis.ca/map [Accessed 9 March 2022]

Stoll-Kleemann S, O'Riordan T (2017) The challenges of the Anthropocene for biosphere reserves. Parks 23(1): 89–100. https://doi.org/10.2305/IUCN.CH.2017.PARKS-23-1SS-K.en

The Ecological Land Classification, 2017 (2018) Statistics Canada. Catalogue no. 12-607-X. Ottawa, Canada, 39 pp.

The Encyclopedia of Saskatchewan (2005) Canadian Plains Research Center, University of Regina Press, Regina, Canada. https://esask.uregina.ca/home.html [Accessed June 2020]

Thuiller W, Albert C, Araújo MB, Berry PM, Cabeza M, Guisan A, Hickler T, Midgley GF, Paterson J, Schurr FM, Sykes MT, Zimmermann NE (2008) Predicting global change impacts on plant species distributions: Future challenges. Perspectives in Plant Ecology, Evolution and Systematics 9(3–4): 137–152. https://doi.org/10.1016/j.ppees.2007.09.004

UNESCO (n.d.) Man and the Biosphere Programme (MAB). Biosphere Reserves. Redberry Lake. https://www.unesco.org/en/mab/redberry-lake?hub=66369 [Accessed 11 November 2024]

Venter O, Brodeur NN, Nemiroff L, Belland B, Dolinsek IJ, Grant JWA (2006) Threats to endangered species in Canada. Bioscience 56(11): 903–910. https://doi.org/10.1641/0006-3568(2006)56[903:TTESIC]2.0.CO;2

VHPRSK (n.d.) Virtual Herbarium of Plants at Risk in Saskatchewan: A natural heritage. W.P. Fraser Herbarium (SASK) at the University of Saskatchewan. https://biolwww.usask.ca/rareplants_sk/root/htm/en/researcher/1_intro.php [Accessed 12 January 2024]

Whitelaw G, Schmutz JK (2010) Redberry Lake Biosphere Reserve periodic review. Canadian Commission for UNESCO, Ottawa, Canada, 39 pp.

Supplementary material 1

Taxonomic and conservation status of threatened vascular plants of the Redberry Lake Biosphere Region

Authors: Vladimir Kricsfalusy

Data type: pdf

Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0/). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.

Link: https://doi.org/10.3897/natureconservation.63.177517.suppl1